ASDMCon

Advanced Sensor Based Defect Detection and Management at Construction Sites

Burcu Akinci, Assist. Prof., bakinci@cmu.edu

http://www.ce.cmu.edu/~itr/

Carnegie Mellon

ASDMCon Participants

Faculty:
CEE: Burcu Akinci, Jim Garrett, Mark Patton

Robotics: Martial Hebert, Scott Thayer

Architecture: Ramesh Krishnamurti

Postdocs:
Robotics: Daniel Huber, Nicolas VanDapel (P)

Graduate Students:
CEE: Frank Boukamp, Chris Gordon, Sameer Khadkatkar (P)

Robotics: Ed Latimer, Rajiv Saxena, DeWitt Latimer (P), Bob Wang (P)

Architecture: Kuhn Park

Undergraduates:
CEE: Sarah Schrass, Martha Alunkal(P)

ECE: Peter Allen

Robotics: Lisa Michaux-Smith, Jennifer Lin

Architecture: Don Havey, John Oduroe (P)

Outline

- Motivation
- ASDMCon Approach
- Case studies
  - A warehouse construction
  - An office and precast manufacturing plant construction
  - Processes:
    - Three Dimensional Modeling
    - Laser scanning
    - Object Recognition
    - Scan planning
    - Embedded Sensing and Planning
    - Defect detection and categorization
- Conclusion and future activities

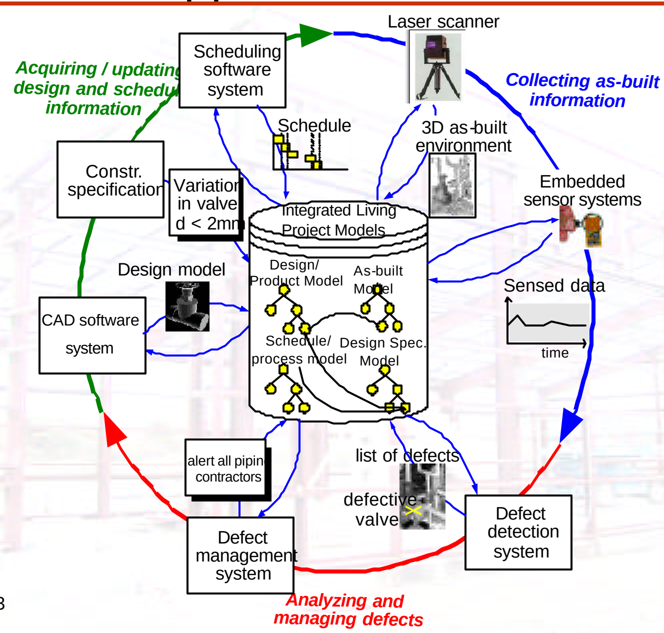
Motivating Problem

- Defects waste time and money (6-18%) and impact the overall performance of the built environment. (Burati and Farrington 1987; Josephson and Hammurland 1998; Patterson and Ledbetter 1989)
- "20-40% of all site defects are caused at the construction phase." (Patterson and Ledbetter, 1989)
- 5-10% of construction cost should be spent on inspection.
  - Issues exist in data collection and data interpretation
- Not having a complete project history of as-built conditions of facility components results in a waste of time and money during operation and maintenance.

Motivating Technologies

- Laser scanners for quickly creating 3D models of the built environment.
- Embedded sensors to monitor performance of components and materials.
- Integrated project model descriptions (e.g., IFC, CIMSteel, etc.) to transfer data and to create an integrated as-designed and as-built models.

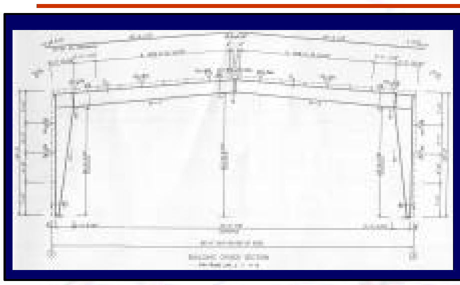
ASDMCon Approach

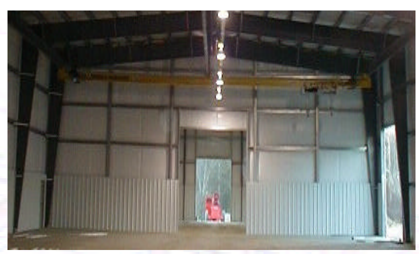


Research Areas/Objectives

- Scan planning
  - Developing general “next-best-view” algorithms
- Sensor planning
  - Developing formalisms and strategies for allocating sensors to collect relevant quality related information.
- Object recognition
  - Developing mechanisms for recognition of facility components
- Integrated “living” project models
  - Developing a representation schema and mechanisms for storing multiple views in a project model (3D design/construction models).
  - Developing a construction specifications model within the integrated project models.
- Automating defect detection
  - Developing a formalism to identify and categorize construction defects.

A warehouse project

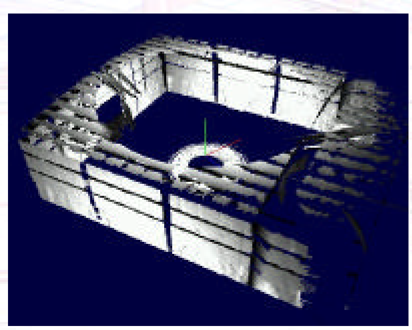




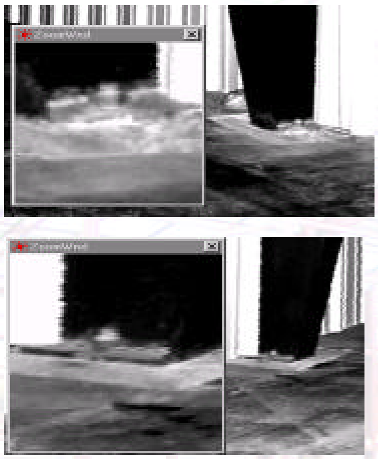
AISC Code of Standard Practice – Section 7.5.1.:

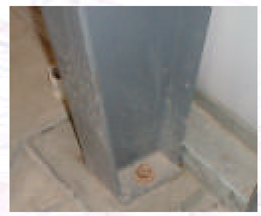
Anchor bolts and foundation bolts are set by the owner in accordance with an approved drawing. They must not vary from the dimensions shown on the erection drawings by more than the following: ...

(e) ***¼-inch from the center of any anchor bolt group to the established column line through that group....***

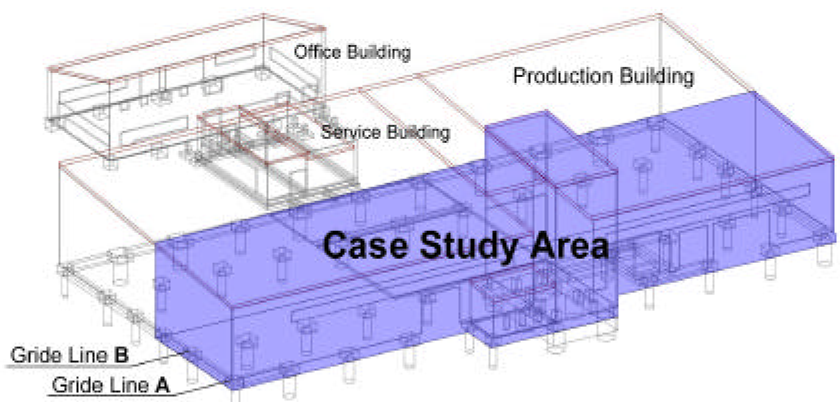


Laser scanners can provide geometric as-built information at the level of detail needed.





A precast manufacturing plant project

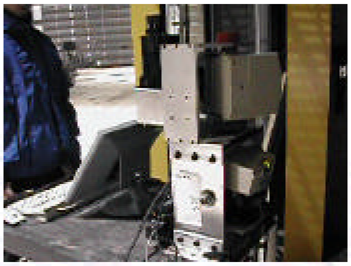


3D Modeling

- Modeling Tool: Graphisoft ArchiCAD 7.0
  - ability to store non-geometric attributes.
  - ability to generate IFC 2x-compliant output for data exchange.
- Design model requirements:
  - 3D and highly detailed.
  - Should incorporate the construction process view.
  - Should include not only geometric info but also performance attributes.

05/30/2003 11

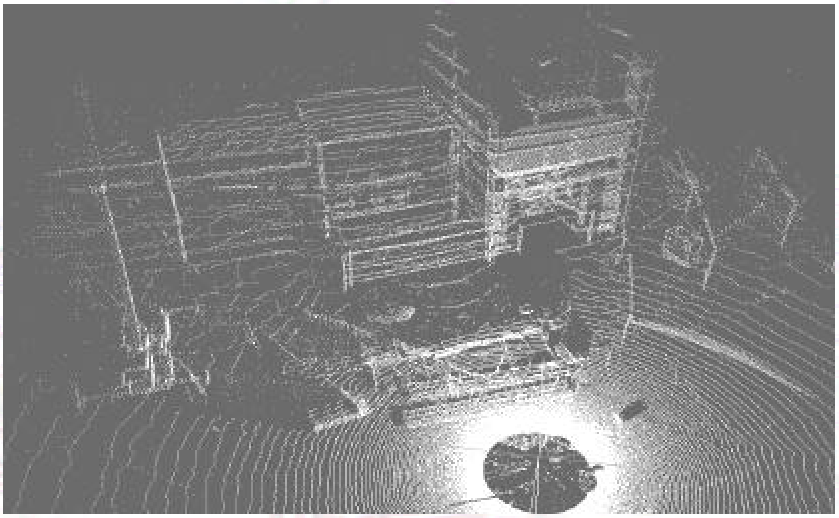
Laser Scanning Process



05/30/2003 12

Example range data

Single laser scan of 150 m length of a building



05/30/2003 13

Laser Scanning Conclusions

- Total saturation of the construction environment with laser scans is inefficient and can be ineffective.
- Sparse scanning risks missing areas of interest that may be occluded or otherwise hard to access for necessary measurements.
- Quality of scans generated is highly dependent on the scan plan.

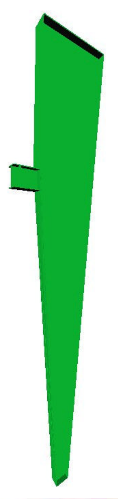
05/30/2003 14

Object Recognition

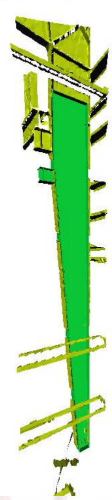
- Need:
  - 3D point cloud output from laser scanning process is not sufficient for high-level reasoning about defects.
  - Objects have to be identified within that point cloud.
- A priori knowledge from design/construction model:
  - Shape comparison of objects.
  - Initial estimate of the location of objects.

05/30/2003 15

Object Recognition Process



Design Model



Recognized Column

Range Data from Laser Scan

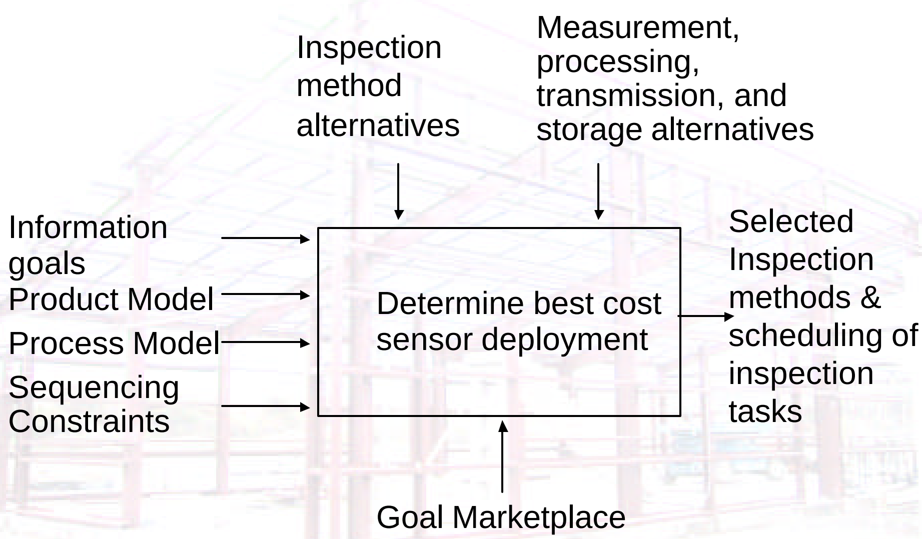
05/30/2003 16

Embedded sensors enable collecting quality info

- Capabilities of certain embedded sensing systems
  - Strain gauges
    - Nucleation and growth of cracks
    - Estimate of shrinkage
    - Estimate of set time and curing rate
  - Temperature gauges
    - Maturity - accurately predict strength
    - Maturity – compliance of mix with specifications
    - Information about curing environment
  - RFID tags
    - ID information, and any programmable information
- Wireless technologies to collect the information

05/30/2003 17

Sensor Planning Approach



05/30/2003 18

Defect Detection and Categorization

- Identify discrepancies between as-built and as-designed models, and compare the discrepancies identified with allowable tolerances described in specs.

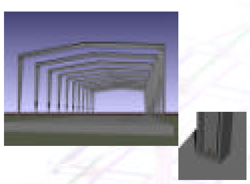
- Short-term approach – Visual inspection:
  - Overlay 3D design model and 3D as-built model to look for discrepancies

- Long-term Vision – Automation:
  - Automating the process of comparing as-built and design models

05/30/2003 19

Vision for Automated Defect Detection

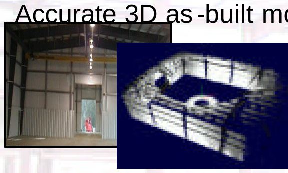
Detailed design model



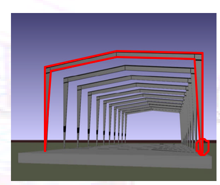
Construction Specifications (e.g. AISC code)

Identify Defects

Accurate 3D as-built models



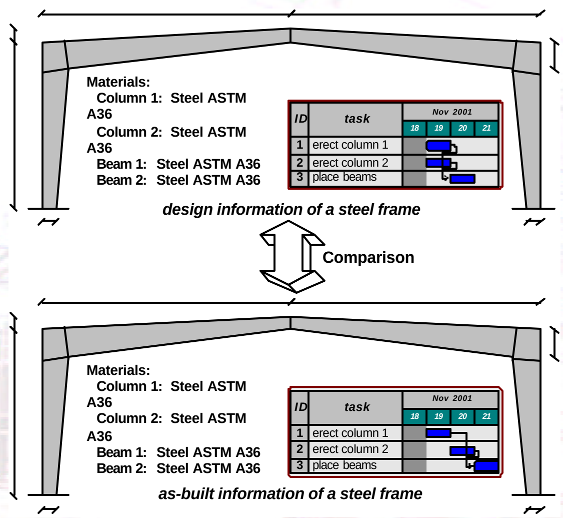
Mechanisms for identifying deviations and categorizing defects



- List of identified and categorized defects
- List of affected building elements

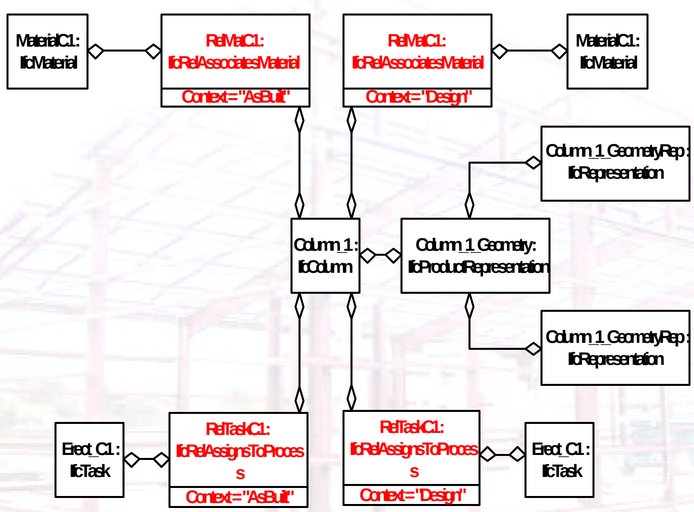
05/30/2003 20

Example Case: Design and As-Built Information of a Steel Frame on the Fibercon Construction Project



- Material information
- Building element type information
- Geometric information (3D)
- Scheduling information
- Relationships between building elements

Integrating as-built and as-designed in IFC



Reasoning about Specifications

- Challenges encountered:
  - Many specifications have to be considered.
  - Even most detailed specifications provided were incomplete:
    - E.g. allowable deviations were not always specified
  - Contradicting specifications were found.
  - Data exchange while assembling the data for comparison with specifications:
    - Data from design, laser scanners and embedded sensors needs to be in the same format.

Overall Conclusions

- Case study validated components of the envisioned approach.
- Laser scanners and embedded sensors can be deployed to collect as-built construction information with project-team cooperation.
- Dependencies and data exchange between different subsystems are complex.
- Current standard data exchange models (e.g., IFC) do not contain all the information needed.